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CHARACTERIZATION OF AMBIENT CHEMICAL CONTAMINANTS IN THE ARMORED VEHICLE ENVIRONMENT

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13. ABSTRACT *(Maximum 200 words)*

Both long-term and short-term sampling techniques are used to qualitatively determine the chemical vapor contaminants in an armored vehicle environment. Ambient air is drawn over sample tubes. The retained vapors are subsequently desorbed and quantified by several analytical techniques. Samples have been collected from the following installations: howitzer firing range, motor pool, and both diesel- and gas-turbine-powered armored vehicle training centers.

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PREFACE

The work described in this report was authorized under Project No. 1O162622A551, Armored System Modification. This work was started in April 1992 and completed in January 1993.

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CHARACTERIZATION OF AMBIENT CHEMICAL CONTAMINANTS IN THE ARMORED VEHICLE ENVIRONMENT

1. INTRODUCTION

There has been interest in whether vapors encountered during operating conditions may affect the performance of a proposed regenerative Collective Protection System (CPS) for armored vehicles. To determine if this concern was valid, the Naval Research Laboratory (NRL) was funded by the U.S. Army Chemical Research, Development and Engineering Center* to conduct a program to identify atmospheric constituents produced during operations with diesel- and gas-turbine-powered tanks.

The approach was derived from previous air sampling and analysis work performed for the U.S. Navy.[1-3] Air samples are collected by drawing atmospheric air through a sampling tube packed with an adsorbent, which traps atmospheric contaminants for future analysis. Data has been collected during basic tank operations such as cross-country maneuvers, road marches, and motor pools. In addition, vapors produced during the firing of artillery rounds were sampled, and their impact on the CPS was assessed. Data was collected on both a short- (hours) and long-term (days) basis.

Once the exposed adsorbent samples have been collected, some or all of the following tests are then performed: weight loss measurements, pH tests, surface area measurements, and gas chromatographic/mass spectrometric (GC/MS) hydrocarbon analysis on carbon disulfide extracts. The weight loss measurements indicate the amount of water present on the carbon and therefore the area unavailable for adsorption of lighter gases. The pH measurements indicate the amount of use or weathering that has occurred on the carbon filters and the presence of ionic species. The surface area measurements indicate how much carbon is available for adsorption. Finally, the GC/MS analysis indicates the degree of weathering as well as the type and relative amount of contaminants present on the carbon.

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*Now known as the U.S. Army Edgewood Research, Development and Engineering Center.

[1]Lamontagne, R., Matuszko, J., Matuszko, R., and Davis, V., Analysis of Weathered Tactical Collective Protection Systems Carbon Filters, NRL Letter Report No. 6180-117, Naval Research Laboratory, Washington, DC, March 1992.

[2]Lamontagne, R., Colton, R., Hoff, H., Rossin, J., Matuszko, R., and Isaccson, L., "Characterization of Weathered Carbon Displaying Agglomeration Tendencies," p 487, In Proceedings of the 1989 U.S. Army Chemical Research, Development and Engineering Center Scientific Conference on Chemical Defense Research, CRDEC-SP-024, U.S. Army Chemical Research, Development and Engineering Center, Aberdeen Proving Ground, MD, August 1990, UNCLASSIFIED Report (AD A229 414).

[3]Lamontagne, R., Isaacson, L., and Matuszko, R., "Characterization of Contaminated Air Purification Carbons," p 285, In Proceedings of the 1988 U.S. Army Chemical Research, Development and Engineering Center Scientific Conference on Chemical Defense Research, CRDEC-SP-013, U.S. Army Chemical Research, Development and Engineering Center, Aberdeen Proving Ground, MD, August 1989, UNCLASSIFIED Report (AD B137 716).

2. SAMPLING LOCATIONS AND CONDITIONS

2.1 Aberdeen Proving Ground Firing Range.

Long-term samplers were installed at U.S. Army Aberdeen Proving Ground (APG), MD, to evaluate the effect of gases and vapors produced during the artillery firings of a *M109 Self-Propelled 155mm Howitzer*. The vehicle was stationary with the sampling system located 20 ft perpendicular to the barrel at a point even with the muzzle. Ambient temperature varied between 80-100 °F with a steady breeze coming off the Chesapeake Bay. Samples were collected over a period of approximately 30 days.

2.2 Recovery School.

Short-term sampling (5-8 hr) was performed at the Combat Vehicle Recovery School at APG to determine the effects of contaminants produced in a diesel engine environment. The site was a mix of open fields and woods of approximately 5 acres. Short-term sampling units were mounted on an M88A1 tracked recovery vehicle, and samples were taken during drills to rehearse the retrieval of disabled vehicles. Since a majority of the operation involved duties at the site of the disabled vehicle, most of the sampling time occurred during idling of the M88A1.

2.3 Fort Hunter-Liggett.

Short-term sampling was performed at Fort Hunter-Liggett, CA, to determine the effects of contaminants produced in a gas turbine engine environment. Samples were collected over a period of approximately 2 weeks. The data was collected during testing sponsored by the Armor Test Directorate in which the new M1A2 tanks were compared with the M1A1 tanks.

Figure 1 shows the bussell rack on an M1A1 tank where the samplers were installed. This rack is located on the back portion of the M1A1 turret and is used mainly for storage. Figures 2 and 3 show the sampling system and bussell rack after the systems were installed on the tank.

Figures 4 and 5 are photographs of Fort Hunter-Liggett, which is located in the desert of central California. Temperatures varied from approximately 50 °F (night) to 105 °F (day) during the 2 week testing period. In general, the wind conditions were fairly calm. The wind was more apparent at night, and there were eddies of wind throughout the testing period.

The Armor Test Directorate's evaluation of the M1A2 tanks against the M1A1 tanks included all the basic operations of these tanks. The four basic operations that M1A1 tanks participate in on a regular basis follow:

a. cross-country maneuvers on a variety of surfaces

b. road marches

c. motor pools

d. gun firings

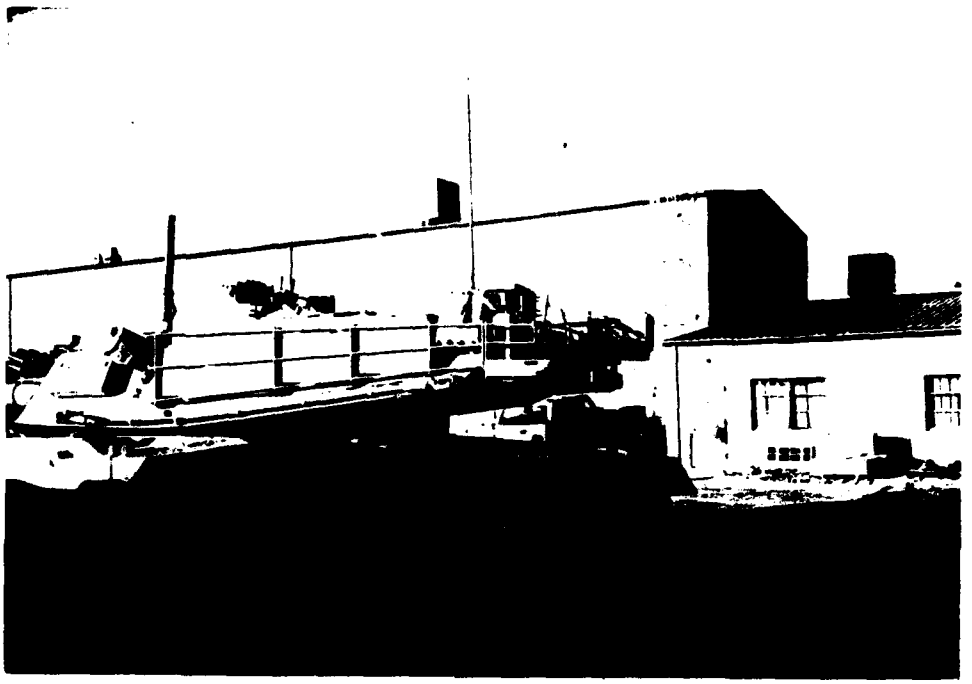

Figure 1. Bussell Rack of M1A1 Tank

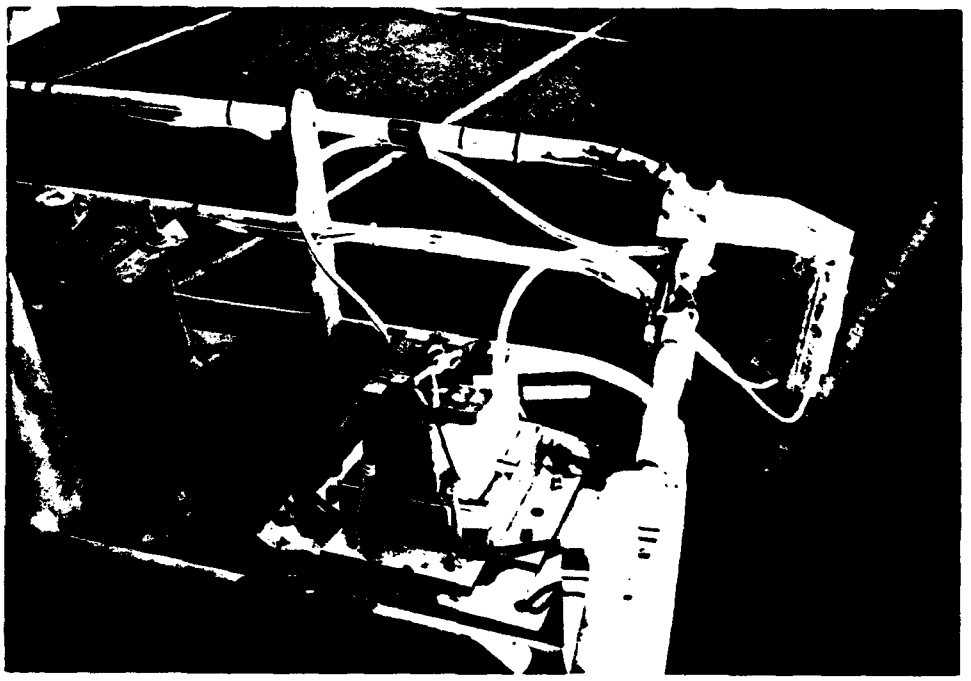

Figure 2. Short-Term Sampling Units Installed on M1A1 Tanks

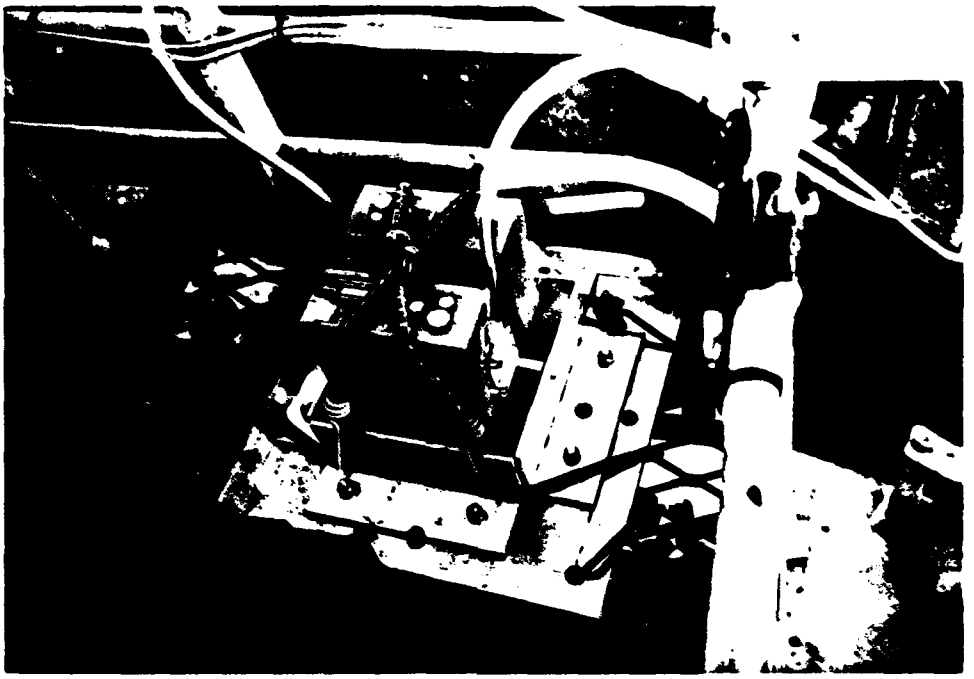

Figure 3. Short-Term Sampling Units Installed on M1A1 Tanks

Figure 4. Ft. Hunter-Liggett, CA, Maneuvers Testing Location

Figure 5. Ft. Hunter-Liggett, CA, Maneuvers Testing Location

Due to the nature of the Test Directorate's evaluation, NRL was able to collect air samples during each of the above listed operations. In addition, some samples were obtained while the tanks were being refueled.

2.4 Fort Hood.

To complement the short-term, gas turbine studies at Fort Hunter-Liggett, long-term atmospheric samplers were installed at Fort Hood, TX. Both gas-turbine-powered M1A1 tanks and diesel powered Bradley fighting vehicles were involved at this site. This study ran from November 1991 through May 1992.

A motor pool and a tank trail were chosen for a 6-month sampling period. The motor pool was partially enclosed with vehicle traffic in, out, and idling during repairs. The sampling equipment was positioned next to the overhead doors. Although this was not the ideal location, it was expected that large concentrations of organic vapors would be present in this area. The tank trail was an open air environment exposed to humidity, rain, and dust.

2.5 Desert Shield/Storm.

Two M48 M1A1 CPS filters that were used in operation Desert Shield/Storm were obtained. The environmental conditions to which these filters were exposed is unknown.

3. EXPERIMENTATION

3.1 Equipment.

Figure 6 shows a long-term atmospheric sampler that is being used for this project as well as being deployed on U.S. Naval ships for a similar project. There are three main components to the sampling system. The first component, labeled with the numeral one on the figure, consists of five tubes, 6 cm (D) by 15 cm (L), filled with either BPL (Calgon Carbon Corporation) or ASC-TEDA (lot number 1183) carbon mounted inside a standard High Efficiency Particulate Air (HEPA) filter. The second component is a volumetric gas flow meter, while the third component is a blower motor. The unit is approximately 60 cm (W) by 60 cm (H) by 122 cm (L) and weighs approximately 68 kg. Atmospheric air is drawn through the filters by the blower attached to the common plenum, and total air volume that has passed through the filters is measured by the flow meter. The carbon tubes can then be removed and replaced with tubes containing unweathered carbon at various intervals.

Figure 7 shows a short-term atmospheric sampling unit used for this study. The sampling system basically consists of two pumps/meters, tygon tubing, carbon sampling tubes, and a metal bracket. The pumps/meters (Model 224-PCXR7) are manufactured by SKC, Incorporated and are compact, programmable, and battery operated. The carbon sampling tubes (SKC catalog No. 226-16-02) are 10 mm x 150 mm and contain 1000 mg of coconut charcoal. Each pump/meter can be programmed to run continuously for up to 8 hr. By using two meters, duplicate samples can be taken concurrently, or the same environment can be evaluated for up to 16 hr.

Dräger tubes (SKC, Incorporated) were employed for the real-time analysis of contaminants. Tubes which quantify hydrocarbon concentrations, were used in conjunction with an SKC-manufactured hand pump.

3.2 Laboratory Procedures.

Once the carbon tubes are removed from the sampling equipment, they are returned to the laboratory and analyzed. Carbon from the long-term samplers are divided into four 3/4-in. sections, measured perpendicular to the air flow, and one remaining section encompassing the rest of the carbon. For the analysis, these sections are labeled 3/4 in., 6/4 in., 9/4 in., 12/4 in., and Remainder. Similarly, carbon from CPS filters (M48 filters) is divided into three 3/4-in. sections perpendicular to the flow. For the analysis, these sections are labeled Inlet(I), Center(C), and Outlet(O). Weight loss measurements, pH tests, surface area measurements, and GC/MS hydrocarbon analysis are then performed on each section. Carbon from the short-term samplers is analyzed using only GC/MS analysis. The following paragraphs will describe the procedure used for each of the analysis techniques.

3.2.1 pH Tests.

The pH tests were conducted by combining 25 mL of double-distilled water with a 1 g sample of carbon, weighed on a Fisher Scientific Series XA Electronic Analytical Balance. pH values were obtained with a Fisher Accumet pH Meter and a Fisher gel combination electrode. Readings were taken after 2 min, 10 min, and 2 hr. As a reference, the pH of a standard (unweathered) carbon in water and the pH of double-distilled water

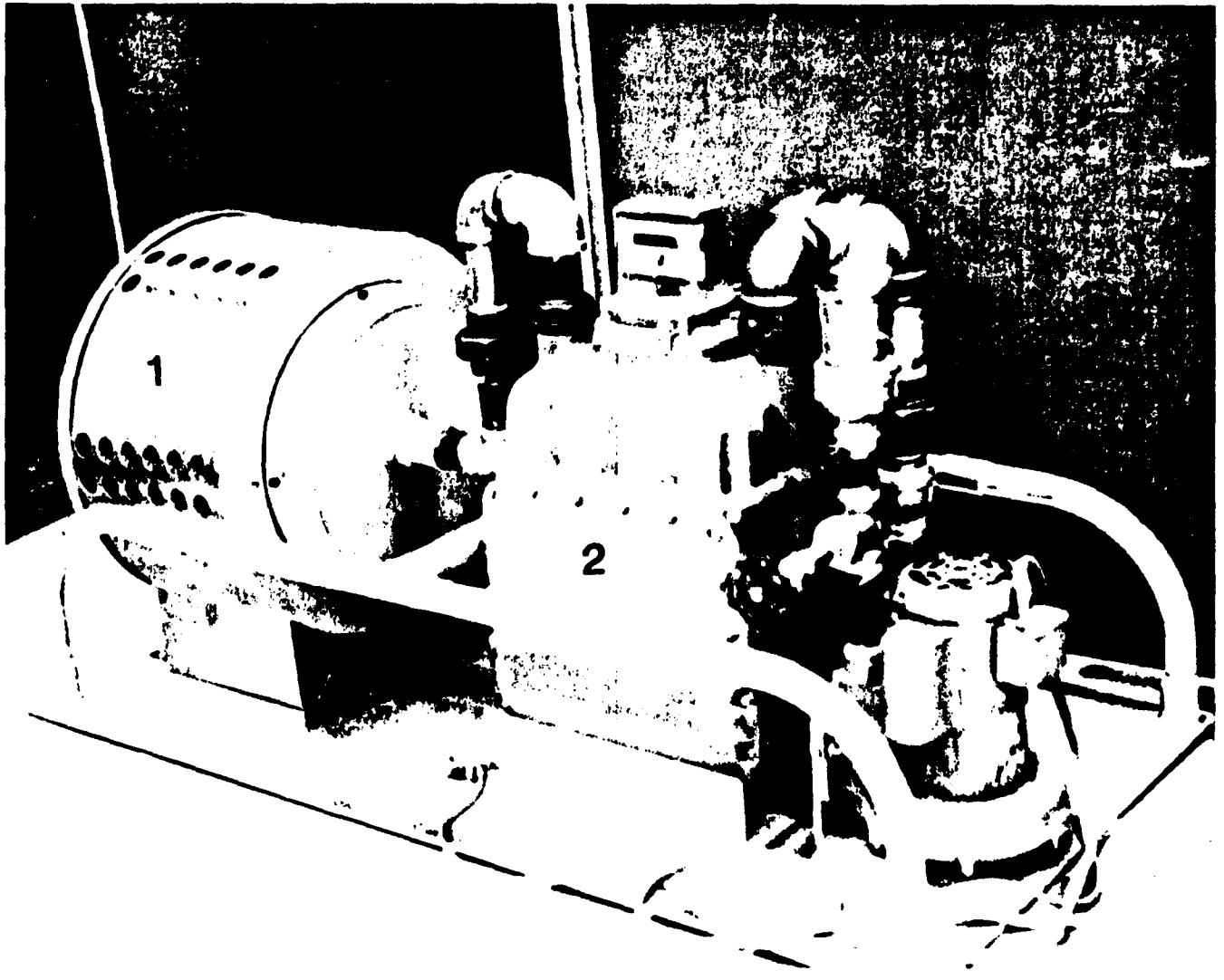

Figure 6. Long-Term Atmospheric Sampling Unit

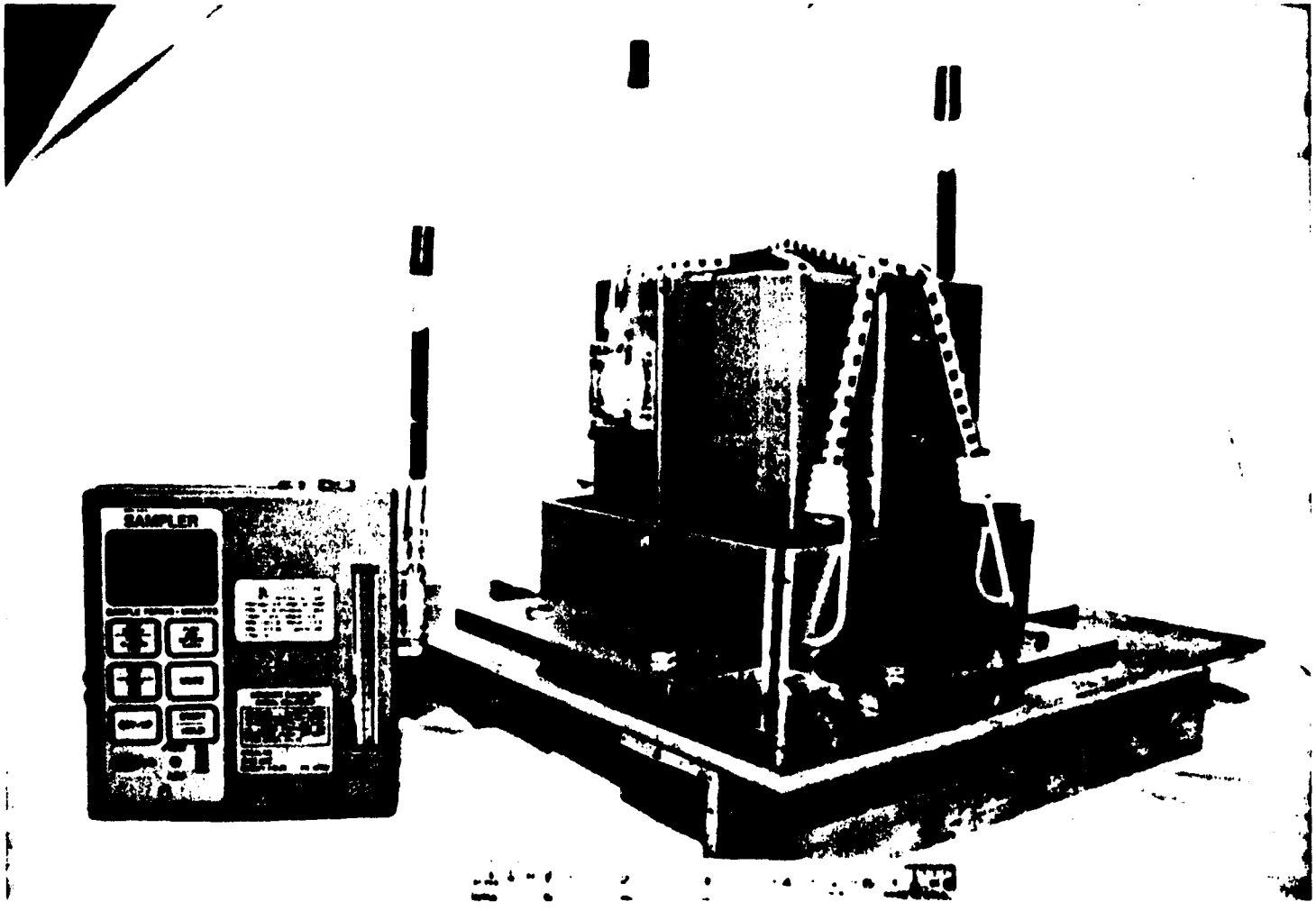

Figure 7. Short-Term Atmospheric Sampling Unit

were also taken. The color and state (effervescence) of the liquid were also noted as they can indicate the degree of weathering.

3.2.2 Weight Loss.

The weight of an empty petri dish was measured on a Fisher Scientific Series XA Electronic Analytical Balance and recorded. Approximately 15 g of carbon were added to the dish, and it was reweighed. The sample was placed in a Blue-M Box Type Muffle Furnace at 150 °C for 3 hr and then cooled in a desiccator. Once it cooled, the sample was weighed again, and the percentage of weight loss was calculated. Previous experience with samples obtained in a Naval environment has shown that the organic speciation is largely unchanged following this heat treatment. For this reason, it is assumed that the loss in weight can be attributed primarily to the volatilization of adsorbed water.

3.2.3 Surface Area.

The nitrogen BET surface area was determined using a Quantachrome Monosorb Instrument. Approximately 0.015 g of sample was used for each determination. Prior to evaluation, each sample was dried by heating it to 110 °C while flushing with dry nitrogen. The surface area of the carbon could then be compared to that of an unweathered reference carbon, which was approximately 1100 m^2/g for the BPL carbon and 700 m^2/g for the ASC-TEDA carbon.

3.2.4 GC/MS Analysis.

The GC/MS tests were conducted on a Varian 3400 Capillary Chromatograph equipped with Varian's Model 8100 Autosampler and a Finnigan MAT Ion Trap Detector. Table 1 shows the operational conditions of the GC. The injection samples were prepared by combining 0.33 g of carbon and 1 mL of carbon disulfide in a glass vial. After overnight refrigeration, a 0.5 μL sample was injected onto the column of the GC.

Table 1. Varian GC Operational Conditions

Instrument:	Varian Model 3400
Column:	Alltech SE 30, OV-1 0.2 μ film 50 x 0.25 mm bonded FSOT
Oven Temperature:	Programmable - 45 °C (3 min hold), ramp 3 °C/min to 105 °C (0 min hold), ramp 7 °C/min to 245 °C (0 min hold) recycle
Carrier Gas:	Helium
Flow (through column):	3 mL/min

4. RESULTS AND DISCUSSION

A literature search was conducted by the CBIAC to determine whether any research had been performed on identifying atmospheric contaminants in an armored vehicle environment. The CBIAC searched DTIC and the Edgewood publication base and did not identify any past reports documenting research in this area.

4.1 Aberdeen Proving Ground Firing Range.

4.1.1 Sample Collection.

Data was collected during the firing of 810 artillery rounds. Three sets of overlapping samples were taken: 270, 540, and 810 rounds. The sampling periods overlapped in such a way that each shorter period was a sub-set of the next larger period, with the 810-round period encompassing the entire test.

The projectiles were sand filled, dummy rounds fired with the standard propellent composed mainly of aluminum perchlorate. Since the composition of the artillery propellent is similar to that used in rocket motors, it is assumed that the exhaust components should be of similar speciation and concentration. The major components found in the exhaust of a rocket motor are listed in Table 2 (personal communication with Bill Butler, Redstone Arsenal, AL).

4.1.2 pH Tests.

The results of the pH tests are listed in Table 3. These values can be compared to a reference, unweathered, BPL carbon with a pH of approximately 8.0. The decrease in the pH of these samples from that of the reference carbon is very significant when compared to the decrease that has been documented for carbon weathered for a comparable time period in the absence of artillery exhaust (a decrease from 8.0 to 7.7).[1,3] However, it should be noted that the referenced studies were performed with TEDA impregnated carbon. The impregnation process imparts various salts on the carbon, creating a potential for pH buffering. Since BPL has no added buffering capacity, it is expected that water extracts of BPL would prove to be more pH sensitive than those of the impregnated carbon.

It appears that the number of artillery rounds fired did not have a significant effect on the differences between the three sets of firings for the first two sections. The last two sections and the remainder show a decrease in overall pH values with increasing rounds fired. The decrease in the carbon pH value of 8 to the respective values for the various artillery firing groups is related to the presence of hydrochloric acid (HCl) vapor. High quantities of HCl are released in the propellent exhaust.

4.1.3 Weight Loss.

Table 4 shows the results of the weight loss measurements. For carbon that has been weathered in a hydrocarbon environment, the amount of water found on the inlet sections is less than that found on the other sections. This occurs because the higher molecular weight hydrocarbons that are collected on the carbon filter can displace the water from the carbon. As filters are in service for longer periods of time, higher molecular weight hydrocarbons move deeper down the filter. Concurrently, the amount of water present in the filter decreases.

Table 2. Composition of Rocket Motor Exhaust

	Grams Produced Per 100 g of Propellant
AlCl	0.01118
$AlCl_2$	0.05611
$AlCl_3$	0.0095
Al	0.00843
Al_2O_3	33.96397
CO	21.95053
CO_2	2.83523
Cl	0.19561
Fe	0.01801
FeCl	0.00327
$FeCl_2$	1.57580
$Fe(OH)_2$	0.00322
H	0.01419
HCl	20.24216
H_2	2.07671
H_2O	8.79125
NG	0.00107
N_2	8.22263
OH	0.02071
Total	99.99963

Table 3. pH Values Obtained for HEL Samples (2-hr Reading)

	Section					
Sample No.	3/4 (In.)	6/4 (In.)	9/4 (In.)	12/4 (In.)	Remainder	Gunnery Rounds Fired
1	5.1	5.5	6.4	7.3	7.0	270
2	5.7	6.3	6.7	6.7	6.8	270
3	5.7	7.2	7.2	7.2	7.5	270
4	5.5	5.8	6.2	6.2	6.3	540
5	5.2	5.8	6.0	6.3	6.6	540
6	4.9	5.6	5.8	5.9	6.7	540
7	5.7	5.9	6.2	6.2	6.2	810
8	5.4	5.8	6.0	6.4	6.1	810

*Reference Carbon (BPL) pH ≈ 8.0

Table 4. Percentage of Weight Loss of HEL Carbon Following Heating (150 °F) for 3 hr

	Section					
Sample No.	3/4 (In.)	6/4 (In.)	9/4 (In.)	12/4 (In.)	Remainder	Gunnery Rounds Fired
1	14.4	8.5	6.3	4.7	11.7	270
2	10.5	7.7	6.2	5.2	5.8	270
3	8.8	5.3	4.2	3.3	3.4	270
4	11.6	9.2	6.6	5.9	5.7	540
5	11.8	8.1	6.7	5.4	5.6	540
6	12.7	9.5	6.8	6.3	6.6	540
7	14.8	10.5	9.0	7.2	7.1	810
8	14.9	10.9	9.0	8.0	6.8	810

The weight loss measurements obtained in this artillery environment show a different trend than data obtained in a hydrocarbon environment. In general, the amount of water found on the bed was greatest at the inlet portion and decreased with increasing bed depth. One exception was the exit (remainder) section of the #1 sample tube, which may be attributable to experimental error. The increased water present at the inlet portion of the carbon filters could very well be the result of an enhancement in surface hydrophilicity stemming from the increased HCl loading inferred from the pH study.

4.1.4 Surface Area.

Table 5 shows the surface area values obtained for each sample. In general, the area available for adsorption following weathering in an artillery environment is not significantly different than the area available in an unweathered sample.

Table 5. Surface Area of HEL Carbon Samples (m^2/g)*

	Section					
Sample No.	3/4 (No.)	6/4 (No.)	9/4 (No.)	12/4 (No.)	Remainder	Gunnery Rounds Fired
1	1281	720	1027	1358	1060	270
2	1063	1158	1017	1131	966	270
3	1077	1103	998	1038	1037	270
4	1196	1122	1022	1073	1056	540
5	1061	1067	1006	1079	1025	540
6	889	1082	1054	1087	1161	540
7	1104	1040	1005	1075	966	810
8	1061	1097	1004	918	1100	810

*Reference Carbon (BPL) surface area $\approx$ 1100 m^2/g

4.1.5 GC/MS Analysis.

GC/MS analysis indicates that no measurable hydrocarbons were present on the carbon samples.

4.1.6 Summary.

The results from the weight loss measurements and GC/MS analyses indicate that there are no measurable hydrocarbons present in this artillery environment. The pH measurements indicate that a compound (or compounds) is present, which causes the pH value of the carbon samples (particularly the inlet samples) to become acidic. The acidic pH is probably due to HCl since it makes up 20% of the composition of the propellent exhaust.

However, surface area measurements indicate that weathering of this type does not adversely affect the available adsorption area of the carbon.

4.2 Recovery School.

4.2.1 Sample Collection.

Samples were taken during the recovery of disabled vehicles. In all cases, the pumps/meters were set to a flow rate of 2 L/min. Samples tubes for these tests were placed directly in the exhaust plume of the recovery vehicle.

4.2.2 GC/MS Analysis.

Since the volume of carbon in the short term sampling tubes is small, only GC/MS analysis was performed on the samples. The GC/MS results indicate that only very heavy straight and branched aliphatic hydrocarbons are present on the sample. The hydrocarbons appear to be in the range of C_{14} and above.

To supplement the carbon samples, Dräger tube samples for high molecular weight hydrocarbons were taken. Results from the Dräger tubes support the GC/MS results, indicating high molecular weight hydrocarbons in the diesel exhaust measuring approximately 1740 ppm.

4.2.3 Summary.

GC/MS analysis, supported by Dräger tube samples, indicate that only trace amounts of very high molecular weight hydrocarbons were present (measurable) in these short-term samples.

4.3 Fort Hunter-Liggett.

4.3.1 Sample Collection.

Samples were taken under various tank operations as stated above. In all cases, the pumps/meters were set to a flow rate of 2 L/min. Table 6 lists the samples obtained and the conditions under which they were obtained. In the table, day-time tank operations are referred to as "A," while evening operations are referred to as "B." Background samples were obtained for each day of testing.

During Tank Tests 8 and 12, there were four different M1A1 tanks evaluated. Three of the tanks had a sampling system in the bussell rack. The tests conducted during Tank Test 8 were individual live-round tests. The tank began at a central location and proceeded out to a firing range to participate in various gun firing tests. In some cases, the tank was simply idling; in other cases, the tank was firing while moving. Tank Test 12 was different in that the four tanks collectively participated in a test scenario similar to that described for Tank Test 8.

The OP-4 testing was conducted only in the day and consisted of idling time (motor pool), road marches, and cross-country maneuvering. Four M1A1 tanks (three of which were equipped with a sampling device) participated in the operation along with six

Table 6. Fort Hunter-Liggett Samples

Sample No.	Collection Time (min)	Tank Operation
1	146	Tank Test 8A
2	240	Tank Test 8A
3	176	Tank Test 8A
4	313	Tank Test 8B
5	480	Background Sample (Tank Test 8A)
6	280	Background Sample (Tank Test 8B)
7	244	Tank Test 12A
8	261	Tank Test 12A
9	165	Tank Test 12B
10	166	Tank Test 12B
11	315	Background Sample (Tank Test 12A/12B)
12	480	OP-4 Tests and Refueling
13	283	OP-4 Tests and Refueling
14	310	OP-4 Tests and Refueling
15	480	OP-4 Tests and Refueling
16	285	OP-4 Tests and Refueling
17	480	Background Sample (OP-4 Tests)
18	480	OP-4 Tests
19	284	OP-4 Tests
20	284	OP-4 Tests
21	480	OP-4 Tests
22	284	OP-4 Tests
23	480	Background Sample (OP-4 Tests)
24	421	Tank Test 8B and 12B
25	1491	Tank Test 8A, 12A, OP-4 Tests and Refueling

diesel-powered Bradley fighting vehicles. Selected samples were collected during field refueling.

Sample tubes 24 and 25 in Table 6 are unique in that the sampling time is longer than the other samples obtained during the testing. The same carbon tube was used for collection during more than one test. Sample tube 24 was exposed for Tank Tests 8B and 12B. Sample tube 25 was exposed for Tank Tests 8A, 12A, and all OP-4 tests.

4.3.2 GC/MS Analysis.

Since the mass of the carbon adsorbent in the sampling tubes was small, only GC/MS analysis was performed on these short-term samples. The GC/MS analysis indicates that no measurable hydrocarbons were present on the carbon samples.

The carbon sampling tubes have a glass wool plug at the tube's entrance to filter out particulates, which may interfere with the carbon adsorbent. Since the environment under which these samples were collected was extremely dusty, it is possible that dust trapped on the wool plug acted as a pre-filter and adsorbed some hydrocarbons before they reached the carbon. To address this possibility, carbon disulfide extracts of the wool were also analyzed by GC/MS. No measurable hydrocarbons were found in the wool plug extracts.

4.3.3 Summary.

The GC/MS analysis of these short-term samples indicates that no measurable hydrocarbon contaminants were present.

An additional observation can be made about the impact the daily operation of heavy/armored vehicles can have on a proposed CPS. During the sampling at Fort Hunter-Liggett, a great deal of dust/particulate matter was generated on a daily basis. It was indicated that up to 50 lb of dust was removed each day from the intake filters of the M1A1's gas turbine engine. Indeed, during one operation, an M1A1 had to be pulled from the test due to engine failure caused by dust ingestion. Personnel familiar with the operation of heavy/armored vehicles indicated that there are similar dust problems everywhere these vehicles go. Because of this, any effort to design an advanced CPS for an armored vehicle should consider the problems associated with the ingestion of large amounts of particulate matter.

4.4 Fort Hood.

4.4.1 Sample Collection.

One carbon tube from the long-term samplers at both the motor pool and the tank trail were removed and replaced with unweathered carbon. This was done each month over a 5-month period. The objective of this change-out philosophy was to obtain a series of samples that overlapped in exposure time. Thus, the overlap would indicate not only how the environment changed on a monthly basis, but also show the effects of long-term filter exposure. Two tubes from the motor pool were broken open in transit while two tubes from the tank trail contained molecular sieve. Data from these four tubes are not considered in this study.

4.4.2 pH.

Water extracts of unweathered, ASC-TEDA carbon tend to produce a slightly basic pH (pH ≈ 8.0) due to the impregnants. As the carbon ages, these impregnants begin to break down, resulting in a decrease in the measured pH. Thus, it can generally be assumed that the longer the service life of a given carbon sample, the more acidic the extract would become.

Table 7 lists the pH values for the tank trail and motor pool samples. The pH values for both sampling areas are lower (more acidic) than those obtained from the reference (unweathered) carbon, reflecting the exposure time and break down of the impregnants. However, it is possible that the lower pH is partially a result of the ingestion of acidic moieties from the exhaust fumes of the motor pool and other atmospheric chemicals brought down with the rain on the tank trail. It should be noted that it was exceedingly rainy during the 5-month sampling period.

Table 7. pH Values Obtained for Fort Hood Carbon Samples (2-hr Reading)*

	Section					
Sample No.	3/4 (in.)	6/4 (in.)	9/4 (in.)	12/4 (in.)	Remainder	Age‡
Motor Pool 1	6.8	6.9	7.0	7.0	7.0	1.2
Motor Pool 6	6.7	7.0	7.1	7.1	7.1	2.7
Motor Pool 7	6.7	7.1	7.1	7.1	7.1	4.3
Tank Trail 9	7.0	7.0	7.0	7.1	7.1	1.[illegible]
Tank Trail 2	6.6	6.8	6.9	7.0	7.0	2.6
Tank Trail 7	7.0	7.0	7.0	7.1	7.1	3.9

*Reference carbon (TEDA) pH = 8.0
‡Age in months

4.4.3 Weight Loss.

Table 8 lists percentage of weight loss for the tank trail and motor pool samples. The weight losses for all of the samples is relatively low, indicating a fairly low concentration of adsorbed water. Since water is not strongly adsorbed on activated carbon, it is possible that water adsorbed during rainy periods was desorbed by the low relative humidity air common to Fort Hood during periods without rain. Since the tubes were not changed out in times of wet weather, the air last processed by the sampler was dry. Thus, the low weight loss observed on these samples is consistent with expectations.

Table 8. Percentage of Weight Loss of Fort Hood Carbon Following Heating (150 °C) for 3 Hr

	Section					
Sample No.	3/4 (In.)	6/4 (In.)	9/4 (In.)	12/4 (In.)	Remainder	Age‡
Motor Pool 1	1.3	1.5	1.6	1.5	1.4	1.2
Motor Pool 6	2.9	3.4	3.5	3.4	3.5	2.7
Motor Pool 7	2.4	2.9	3.5	3.4	3.5	4.3
Tank Trail 9	3.7	3.7	3.8	3.5	3.9	1.8
Tank Trail 2	3.6	3.5	3.6	3.5	3.3	2.6
Tank Trail 7	2.9	3.2	3.4	3.4	3.5	3.9

‡Age in months

The tubes from the motor pool show a slight trend in which the first 3/4-in. section gives a smaller weight loss than the rest of the tube. This trend is consistent with previous samples taken in an environment with high concentrations of organic vapors.[1] Since water is a weakly adsorbed vapor on activated carbon, more strongly adsorbed vapors can displace and prevent water from adsorbing. Therefore, the lower weight loss on the first 3/4-in. tube section indicates an organic loading higher than should be found in the rest of the tube.

4.4.4 Surface Area.

Table 9 lists the surface area measurements obtained for each sample. The data from the tank trail tubes show no measurable loss in available surface area. The first 3/4 in. section of the motor pool tubes shows a slight decrease in available adsorption surface area. This result is consistent with the weight loss studies, indicating a higher organic loading on the first 3/4-in. motor pool tubes.

4.4.5 GC/MS Analysis.

The GC/MS analysis of the tubes from the tank trail shows no significant hydrocarbon contamination. The two older tubes (2 and 7) show a trace of organics on the first 3/4-in. section of the tube. These trace organics can be identified as small amounts of benzene, toluene, and xylene. No other organics were found on any other section of any other tank trail tube.

The three samples analyzed for the motor pool are markedly different than those for the tank trail. Each tube shows a large degree of contamination. The amount of organics reduces for each successive downstream section of the tube. The contamination is comprised of a mix of aliphatic and aromatic hydrocarbons at a ratio of approximately 10:1 aliphatic to aromatic. Hydrocarbon contamination is measurable well beyond the nC_{17}

Table 9. Surface Area of Fort Hood Carbon Samples (m^2/g)*

	Section					
Sample No.	3/4 (In.)	6/4 (In.)	9/4 (In.)	12/4 (In.)	Remainder	Age‡
Motor Pool 1	588	720	739	687	676	1.2
Motor Pool 6	357	674	615	727	716	2.0
Motor Pool 7	433	688	628	674	623	4.3
Tank Trail 9	664	516	630	639	647	1.8
Tank Trail 2	646	682	680	728	712	2.6
Tank Trail 7	504	774	568	685	684	3.9

*Reference carbon (TEDA) surface area ≈ 700 m^2/g
‡Age in months

standard. The organic distribution is similar to that found on selected U.S. Navy ships in a previous study.[1] This study identified the source of the organics as jet and/or diesel fuel. A more detailed analysis of the GC/MS results for each motor pool tube can be found in the Appendix.

4.4.6 Summary.

The GC/MS and weight loss measurements indicate that there is significant hydrocarbon contamination on the long-term samples from the motor pool. Samples from the tank trail show no indication of hydrocarbon contamination. The pH results for both the motor pool and tank trail indicate that the impregnants on the samples had degraded slightly due to the environmental weathering.

4.5 Desert Shield/Storm.

4.5.1 Sample Collection.

Two M48 filters (serial No. 5176 and 5178) used in operation Desert Shield/Storm were received, broken open, and sectioned into three (I, C, O) separate sections. Analysis was performed separately for each section of each filter.

4.5.2 pH.

Carbon from an unweathered M48 filter that had been stored in a plastic container was used as reference for this analysis. The data for these test can be found in Table 10. The results indicate that little or no weathering of the impregnants on the carbon has taken place.

Table 10. pH Values Obtained for Saudi M48 Filter Samples (2-hr Reading)*

	Section		
Sample No.	Inlet	Center	Outlet
5176	7.9	7.9	8.0
5178	7.8	7.8	7.9

*Reference carbon (ASC Whetlerite) pH = 7.5

4.5.3 Weight Loss.

Table 11 gives the results for the weight loss test for each carbon sample. The weight losses for each sample fall between 11 and 15%, indicating that the carbon has adsorbed some water. However, the distribution of water is homogeneous throughout the filter, indicating that little or no hydrocarbon contamination is present to disrupt the water adsorption.

Table 11. Percentage of Weight Loss for Saudi M48 Filter Samples Following Heating (150 °C) for 3 hr

	Section		
Sample No.	Inlet	Center	Outlet
5176	11.7	10.9	11.6
5178	14.5	13.5	12.7

4.5.4 Surface Area.

No surface area analysis was performed on these samples.

4.5.5 GC/MS Analysis.

The GC/MS analysis for these samples show that there is no measurable hydrocarbon contamination on either filter.

4.5.6 Summary.

All tests performed on the carbons from the these two M48 filters indicate that there is no measurable hydrocarbon contamination. Indeed, the pH studies indicate that the

filters underwent an insignificant amount of atmospheric weathering. It is possible that these filters had not been used in an active CPS.

5. CONCLUSIONS

The atmosphere from the following tank operations in both diesel and gas turbine environments has been sampled: artillery tests, cross country maneuvers, road marches, idling time, and motor pool operations. Both long- and short-term sampling around artillery firing showed no major effect on the carbon with the exception of lowering the pH of water extracts of the carbon. During short-term sampling in the gas-turbine powered M1A1 tank environment, no hydrocarbon species were collected on the carbon. Therefore, M1A1 tank operations should not have any effect on the collective protection system of the tanks on a short-term basis. However, long-term samples, collected in an M1A1 motor pool environment, show significant accumulations of aromatic and aliphatic hydrocarbons. These hydrocarbons are massive enough to potentially create a long-term impact on a regenerative filtration system. Finally, high molecular weight hydrocarbons have been found on carbon from short-term samples collected around diesel tank operations.

Blank

APPENDIX

GC/MS ANALYSIS OF FORT HOOD MOTOR POOL SAMPLES

Motor Pool tube 1

3/4-in. This sample gave a wide distribution of aliphatic and aromatic hydrocarbons from toluene out to a maximum of nC_{17}. The distribution centers on nC_{10} with nC_{11} being the second largest peak. The aromatics consist of moderately sized toluene and xylene peaks with small amounts of C_3 and higher substituted benzenes. The aliphatics consist of a spectrum of saturated straight and branched hydrocarbons, with a very small amount of unsaturated hydrocarbons. Included with the aliphatic group are small concentrations of saturated cyclic compounds. For this sample, the ratio of aromatics to aliphatics is approximately 1:20.

6/4-in. This sample shows only five peaks of moderate size. The largest peak comes from ethyl cyclohexane. There are four other peaks arising from lighter unidentified aliphatic hydrocarbons.

9/4-in. This sample shows a small single peak identified as methyl cyclohexane.

12/4-in. No organics were found on this sample.

R No organics were found on this sample.

Motor Pool tube 6

3/4-in. This sample gave a wide distribution of aliphatic and aromatic hydrocarbons from toluene out beyond the retention time of nC_{17}. The distribution centers on nC_{11}. The aromatics consist of a large toluene peak, moderately sized xylene peaks, and small amounts of C_3 and higher substituted benzenes. The aliphatics consist of a spectrum of saturated straight and branched hydrocarbons, with a very small amount of unsaturated hydrocarbons. Included with the aliphatic group are small concentrations of saturated cyclic compounds. The ratio of aromatics to aliphatics for this sample is approximately 1:20.

6/4-in. This sample gives a range of aliphatic and aromatic hydrocarbons out to nC_{10}. The distribution centers between nC_7 and nC_8 with the dominant peak being benzene. The aromatics consist of the large benzene peak with a moderately sized toluene peak. The aliphatics are represented by a few shorter chain straight and branched hydrocarbons, with some saturate branched hydrocarbons in the range of C_6 - C_8. For this sample, the ratio of aromatics to aliphatics is approximately 3:2.

9/4-in. This sample shows a small single peak identified as methyl cyclohexane.

12/4-in. This sample shows a small single peak identified as methyl cyclohexane.

R No organics were found on this sample.

Motor Pool tube 7

3/4-in. This sample gave a wide distribution of aliphatic and aromatic hydrocarbons from toluene out beyond the retention time of nC_{17}. The distribution centers on nC_{10}. The aromatics consist of a large toluene peak, moderately sized xylene peaks, and small amounts of C_3 and higher substituted benzenes. The aliphatics consist of a spectrum of saturated straight and branched hydrocarbons, with a very small amount of unsaturated hydrocarbons. Included with the aliphatic group are small concentrations of saturated cyclic compounds. The ratio of aromatics to aliphatics for this sample is approximately 1:5.

6/4-in. This sample gives a small group of aliphatic and aromatic hydrocarbons out to nC_9. The largest peak in the group is a moderately sized benzene peak. The benzene peak is the only aromatic hydrocarbon present. The remaining peaks, in trace amounts, have been identified as aliphatic and cyclic compounds in the C_6 - C_9 range.

9/4-in. This sample shows a small single peak identified as methyl cyclohexane.

12/4-in. This sample shows a small single peak identified as methyl cyclohexane.

R No organics were found on this sample.